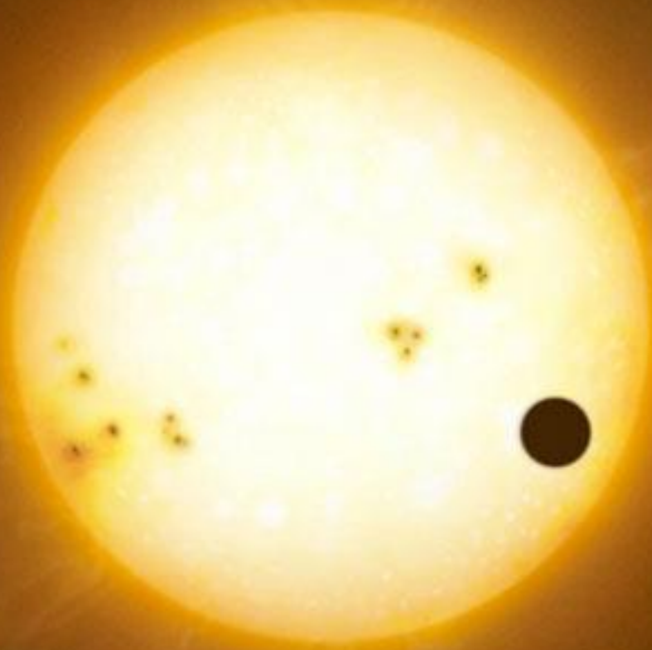
JWST NIRCam Time Series Observations



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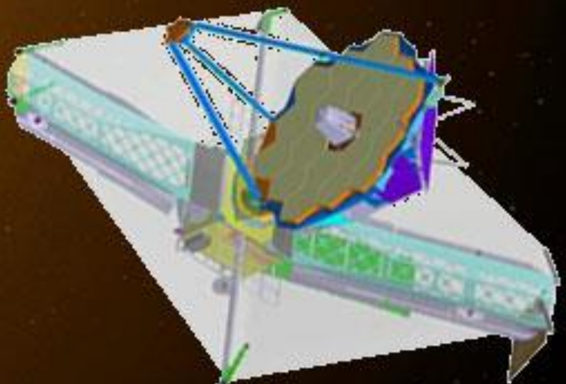


ETEO w/JWST
July 10, 2017

NIRCam Intro (from STScI Jdox)

Introduction

The JWST Near Infrared Camera (NIRCam) observes from 0.6 to 5.0 μm and offers imaging, coronagraphy, and grism slitless spectroscopy. NIRCam has 2 modules pointing to adjacent fields of view. Each module uses a dichroic to observe simultaneously in a short-wavelength channel (0.6–2.3 μm) and a long-wavelength channel (2.4–5.0 μm).

NIRCam has 5 observing modes for science:

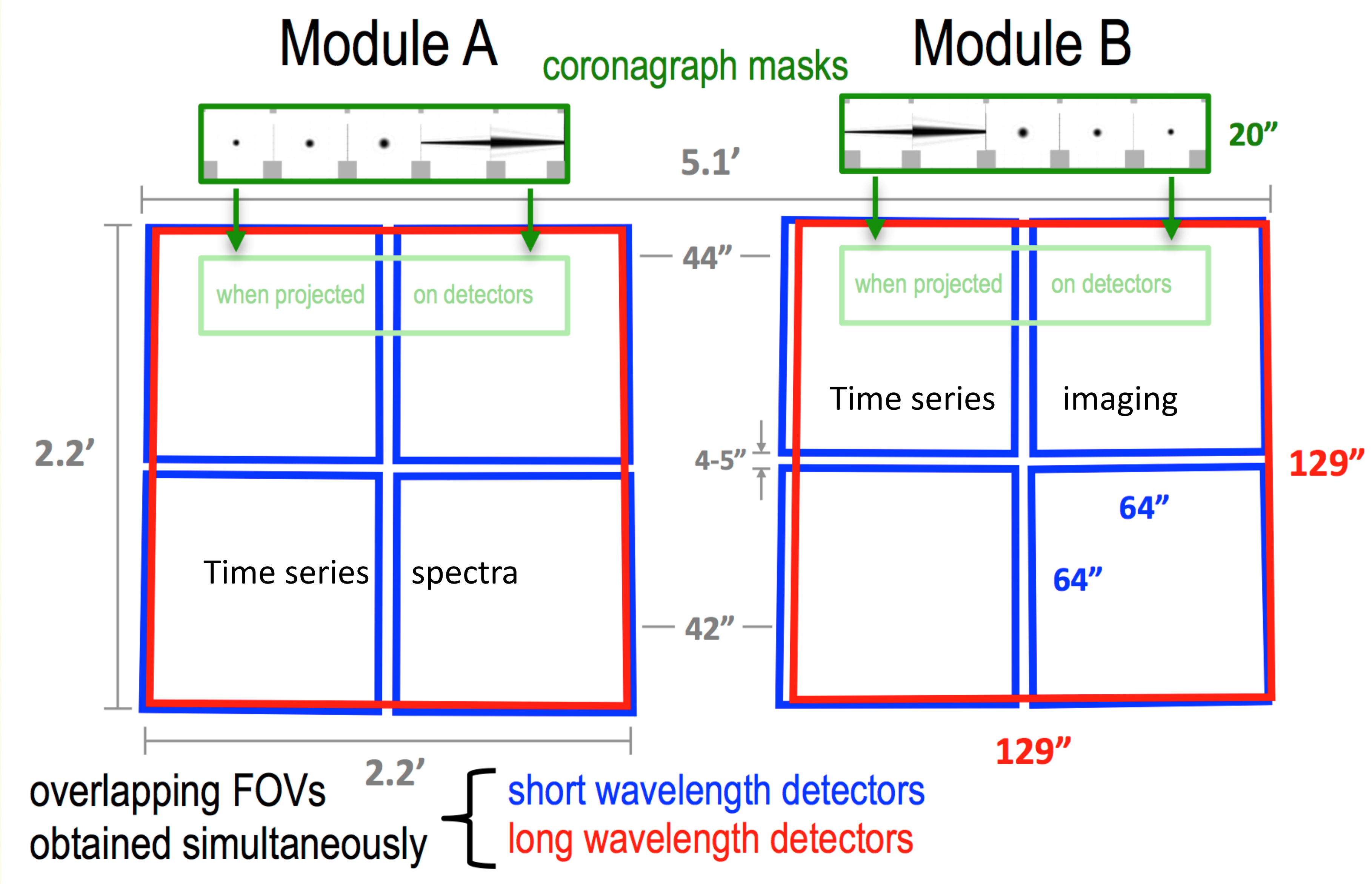
- Imaging of two 2.2' × 2.2' fields separated by 44" covering 9.7 arcmin^2 in total
- Coronagraphic imaging at multiple wavelengths
- Wide field slitless spectroscopy (2.4–5.0 μm) using grisms with resolving power $R = \lambda/\Delta\lambda \sim 1500$
- Time series imaging (photometric monitoring)
- Grism time series (spectroscopic monitoring)

Focus of this talk

NIRCam will also obtain wavefront sensing measurements used to align and phase JWST's primary mirror.

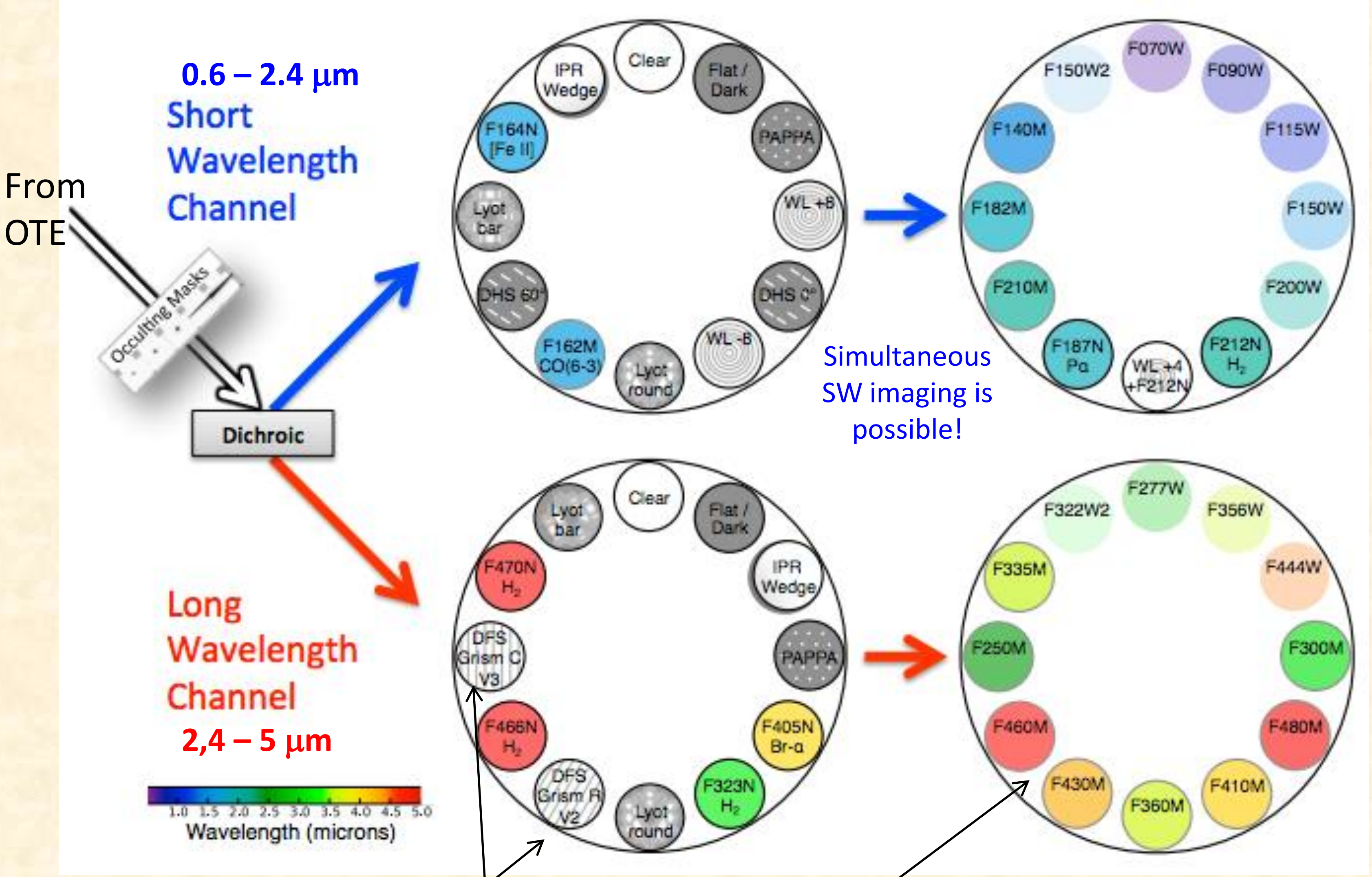
From https://jwst-docs.stsci.edu/display/JTI/

NIRCam Fields of View (from STScI Jdox)



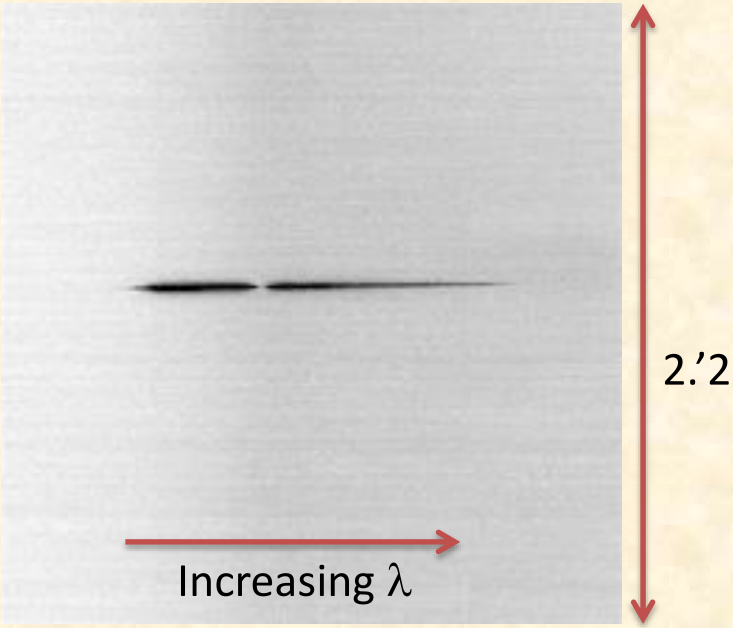
NIRCam modes: selectable with wheels

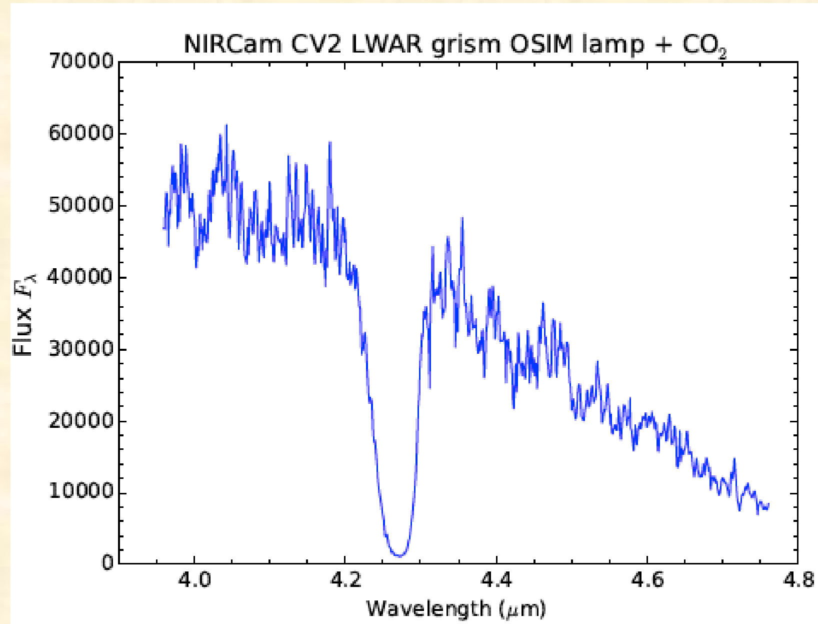
No Short Wavelength Spectroscopic Capabilities in Cycle 1



2 LW grisms in each module provide R~1500 slitless spectroscopy: Chose dispersion orientation and filters to suit your science

NIRCam LW Grism Spectra





Left: NIRCam spectral image of the OSIM super-continuum lamp point source taken with the LWA R grism and F444W filter during JWST instrument testing.

Right: Extracted spectrum. The continuum decreases toward longer wavelengths due to low fiber transmittance, and the broad feature near 4.27 μm is due to CO_2 absorption. These are artifacts of the test equipment and not NIRCam itself.

*** NIRCam FOV is 2.’2 x 2.’2 with dispersion of 10 Å per 0.”065 x 0.”065 pixel**

NIRCam Spectral Coverage & Resolution

NOTE*: Total spectroscopic throughput is the* ***product*** *of Grism curve and selected filter!*

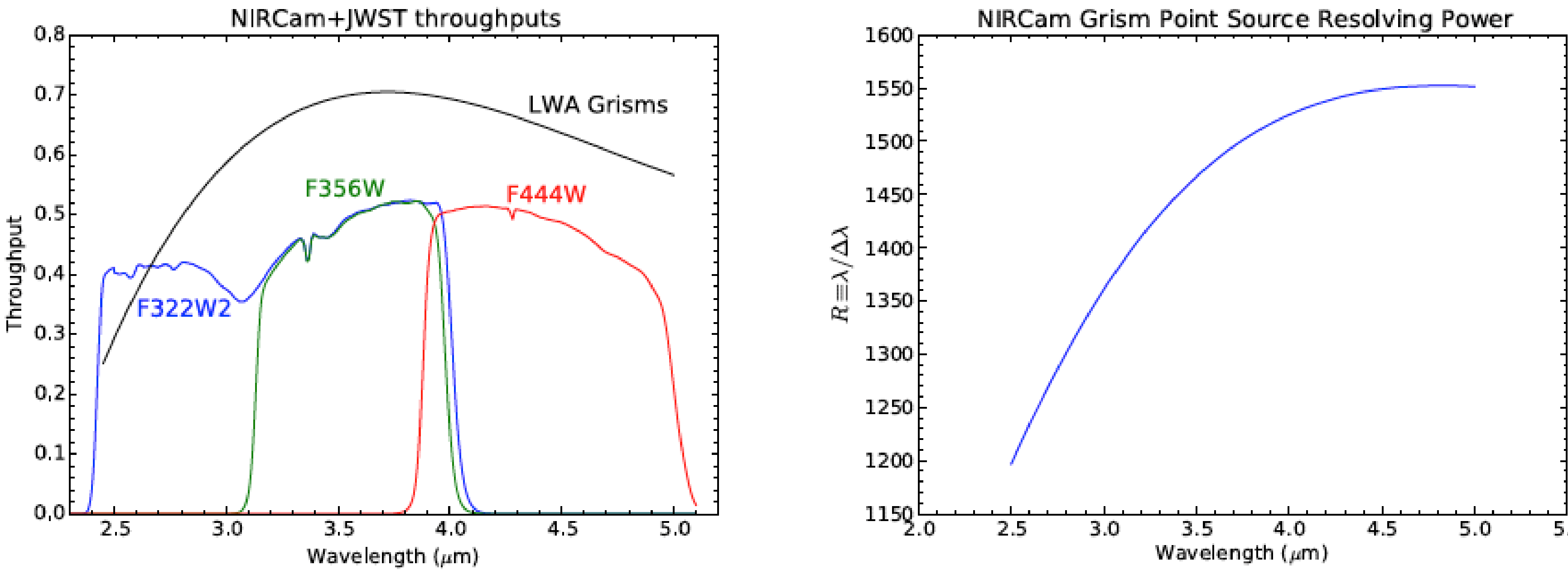


Figure 3. Left: Total system throughput including all OTE and NIRCam optics and the detector quantum efficiency for several NIRCam filters. The theoretical LW grism efficiency curve (shown for the A module) must be multiplied by the filter curves to produce the system throughput at each wavelength. The Module B LW grisms are anti-reflection coated on only 1 side and therefore have throughputs approximately 25% lower than the LWA grisms. Right: Grism FWHM spectral resolving power vs. wavelength for point sources, limited by pixel sampling of the PSF at shorter wavelengths ($\lambda \lesssim 4$ μm) and limited by the circular beam factor[7] and diffraction at longer wavelengths ($\lambda \gtrsim 4$ μm).

Module A (TSO) Spectral Saturation Values

λ (μm)	K_{sat} (A0V)[c]	K_{sat} (M2V)[c]	Filter[d]
2.5	4.3	4.2	F322W2
2.7	4.4	4.4	F322W2
2.9	4.3	4.3	F322W2
3.1	4.1	4.1	F322W2
3.3	4.1	4.3	F322W2
3.5	4.0	4.2	F322W2
3.7	3.9	4.1	F322W2
3.9	3.7	3.9	F322W2
4.1	3.4	3.7	F444W
4.3	3.1	3.4	F444W
4.5	2.9	3.0	F444W
4.7	2.5	2.7	F444W
4.9	2.1	2.4	F444W

NIRCam can observe bright stars!

c: K-band Vega magnitudes for saturation (80% full well or 65,000 electrons) for 0.68 s int

See Greene+ (2017) JATIS article for more Module A & B saturations and sensitivity values

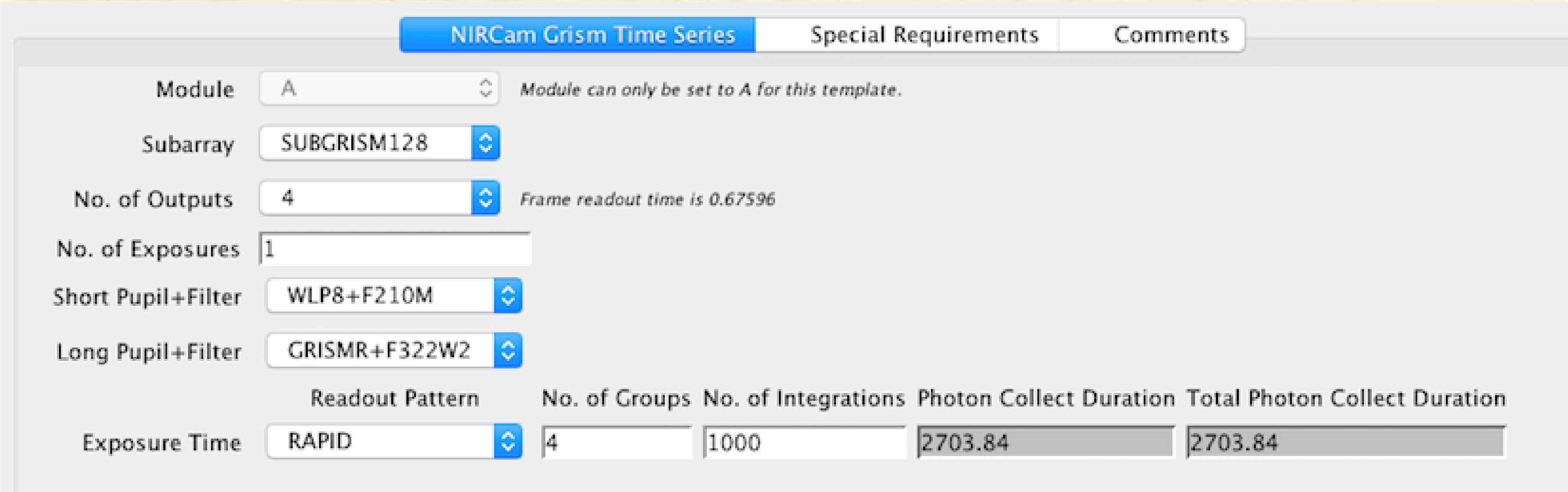
Time-series imaging is also possible

- $\lambda < 2.4\ \mu m$ TSO imaging can be done simultaneously with either $\lambda > 2.4\ \mu m$ imaging or spectroscopy
- SW observations can be done with weak lenses for better bright limits and potentially higher precision photometry
- Show HAT-P-18 b APT example???

Setting TSO parameters

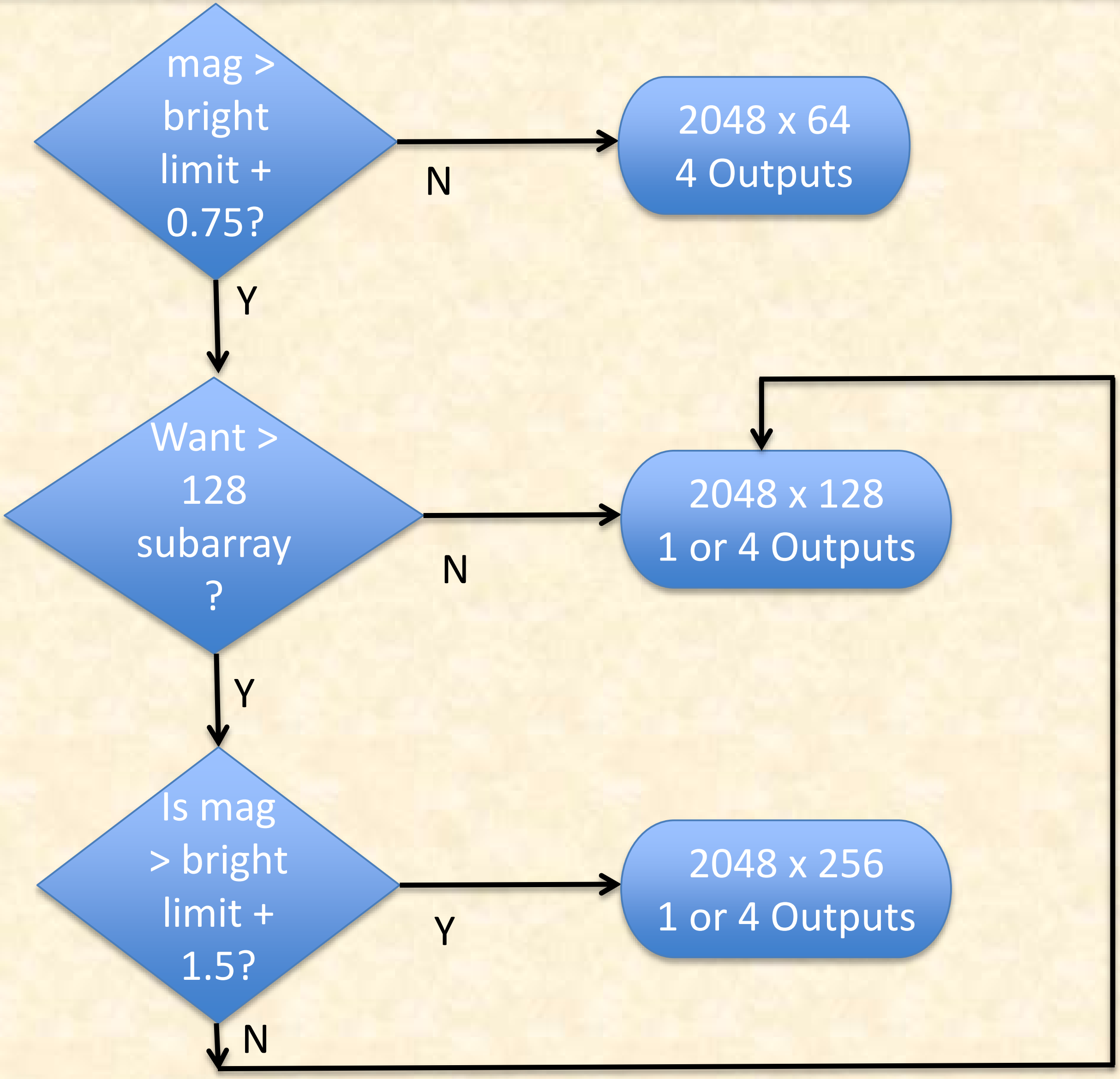
- Determine how much dwell time for each object
- Set subarrays and exposure parameters
- Set SW filter: simultaneous $\lambda < 2.4\ \mu m$ imaging
- Consider target acquisition
  - Offset acquisition required for bright targets in Cycle 1
- Visibility, position angles, and spectral overlaps
- Enter values into APT

NIRCam grism time series options (APT)

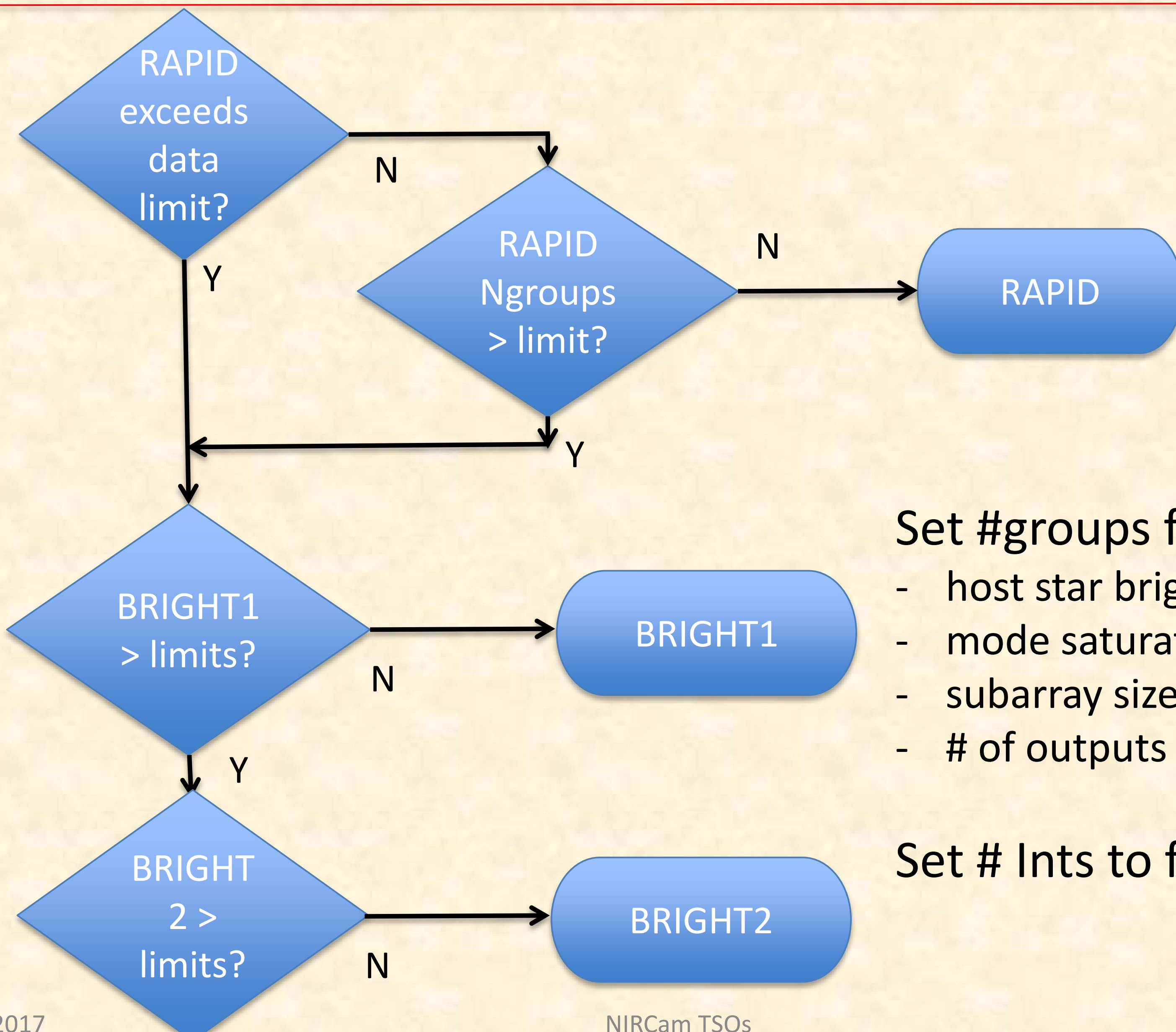


- Can choose from 64, 128, 256, & 2048 x 2048 subarrays
- 1 or 4 outputs (4 for very bright stars)
- Simultaneous short wavelength imaging with weak lens to spread the light over many pixels is possible
- No dithering
- Flexible detector MULTIACCUM exposure & readout parameters

Select Subarray Size



Select Detector Readout Parameters

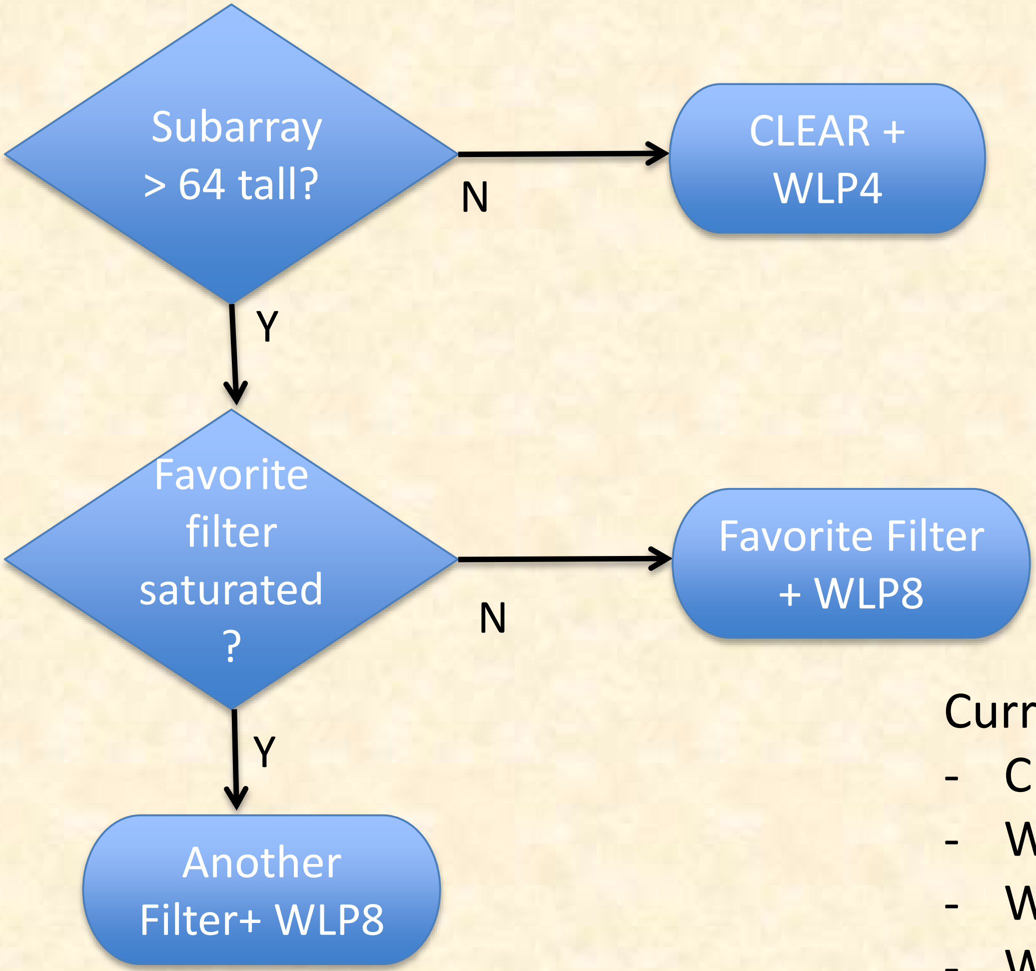


Set #groups from:

- host star brightness
- mode saturation limit
- subarray size
- # of outputs

Set # Ints to fill dwell time

Set SW Filter: Simultaneous λ < 2.4 μm Imaging



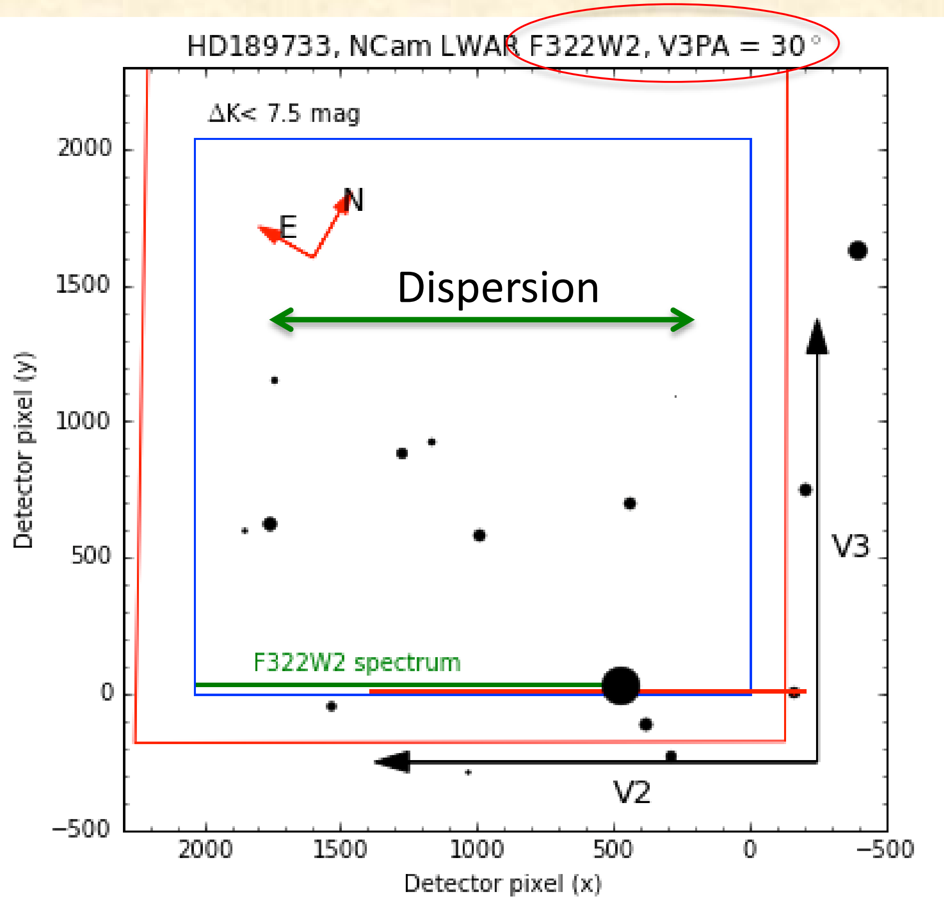
Currently Available SW Filters:

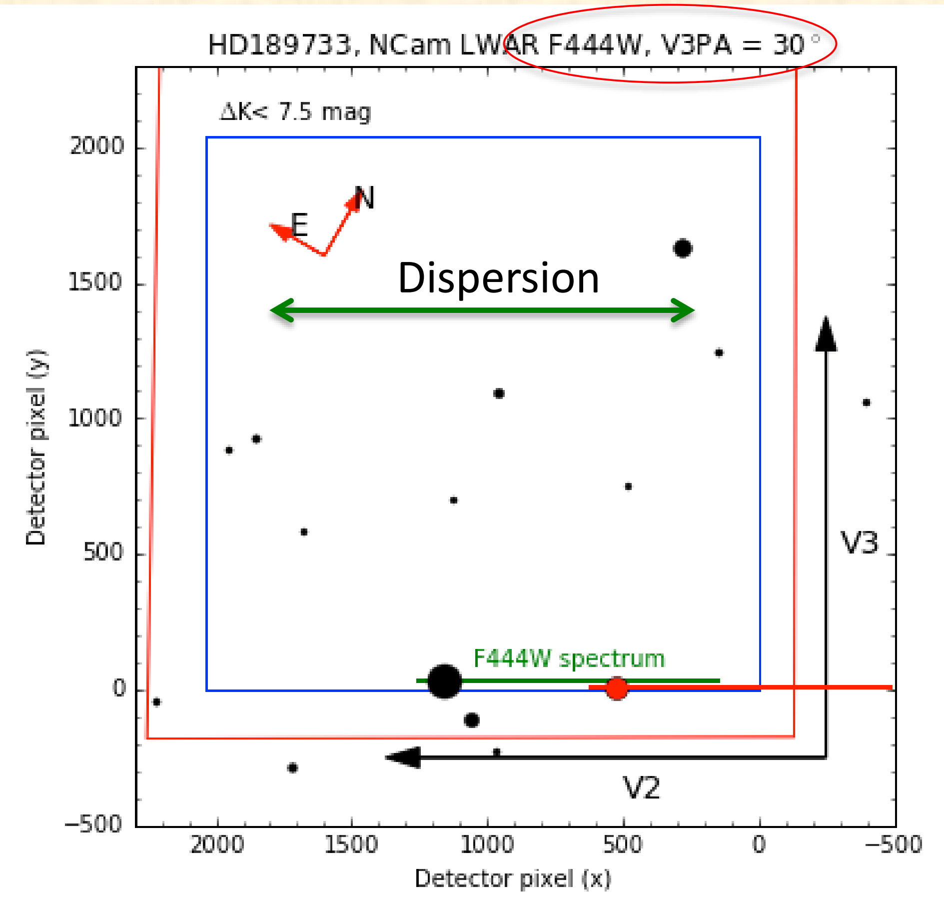
- CLEAR + WLP4
- WLP8 + 182M
- WLP8 + 210M
- WLP8 + 187N
- WLP8 + 212N

Target Acquisition Note

- In Cycle 1, grism time series target acquisition is done with F335M filter, 32 x 32 subarray, and Ngroups ≥ 3
  - Saturation limit is K = 7.0 mag
- *Stars with K < 7.0 may require offset target acquisition*
  - Offset from nearby fainter star with known coordinates
- Using a narrow-band acquisition filter would allow acquiring on K < ~4.5 mag stars (likely Cycle 2 and later)

Check spectral overlap of nearby objects





We are working on an automated tool for this (NIRCam + MIRI LRS)

APT Example: WASP-80 b F322W2

Observation 3 of JWST Draft Proposal (NIRCam_GTO_transiting_planets_APT_ES_2015May25.aptx)

Number: 3 Status: UNKNOWN

Label:

Instrument: NIRCAM

Template: NIRCam Grism Time Series

Target: 3 WASP-80

	Splitting Distance	Number of Visits
Visit Splitting:	65.0 Arcsec	1

	Science	Total Charged
Duration (secs)	19717	32495

Data volume: 25,122 MB

NIRCam Grism Time Series | Special Requirements | Comments

Target Acquisition Parameters

	Acq Target	Acq Subarray	Acq Filter
Target ACQ	Same Target as Observation	SUB32TATSGRISM	F335M

	Acq Readout Pattern	Acq Groups/Int	Acq Integrations/Exp	Acq Total Integrations	Acq Total Exposure Time
Acq Exposure Time	RAPID	5	1	1	0.087

Grism Time Series Parameters

Module can only be set to A for this template.

Subarray: SUBGRISM256

No. of Output Channels: 4 *Frame readout time is 1.34668*

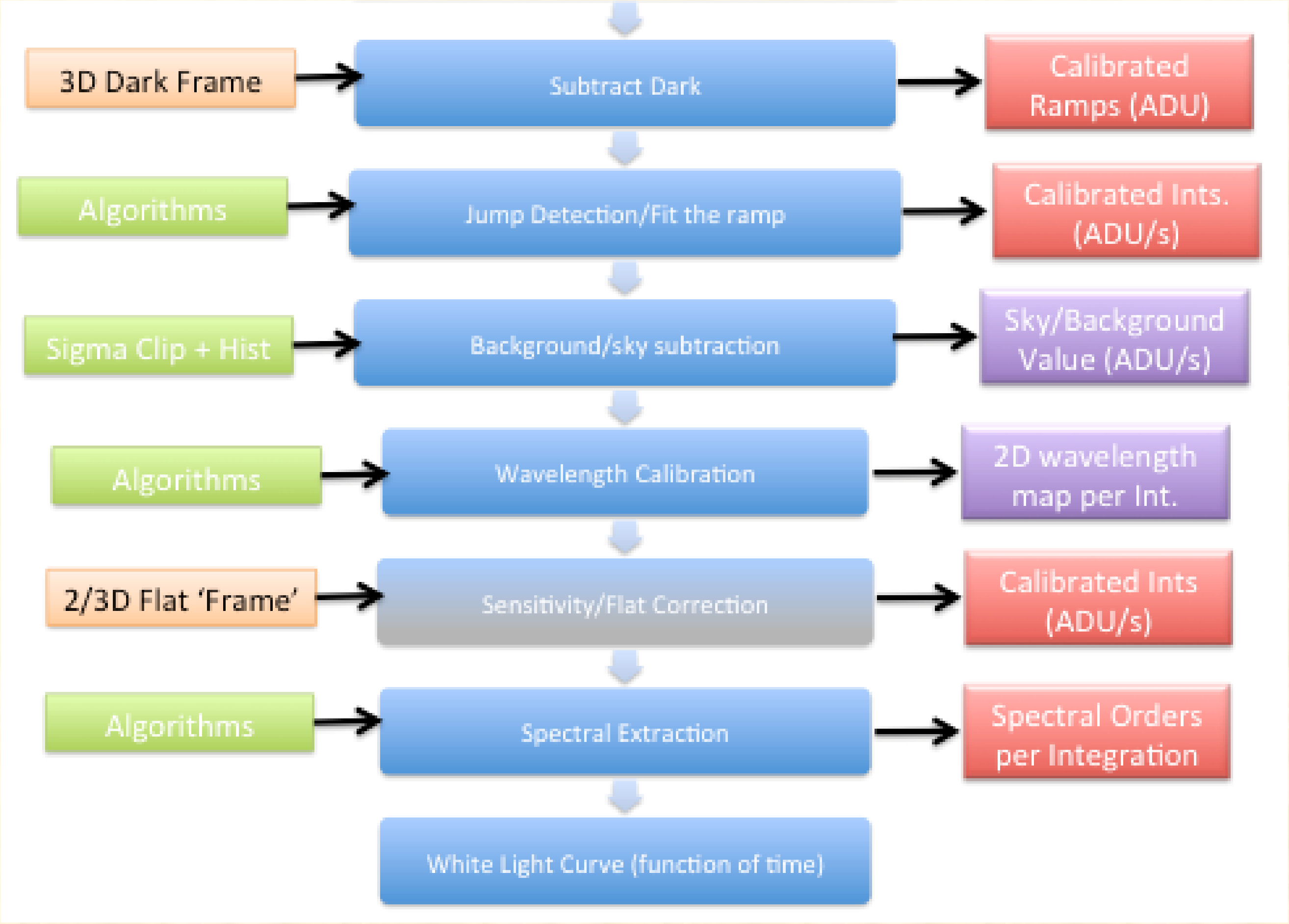
Exposures/Dith: 1

Short Pupil+Filter: WLP8+F210M

Long Pupil+Filter: GRISMR+F322W2

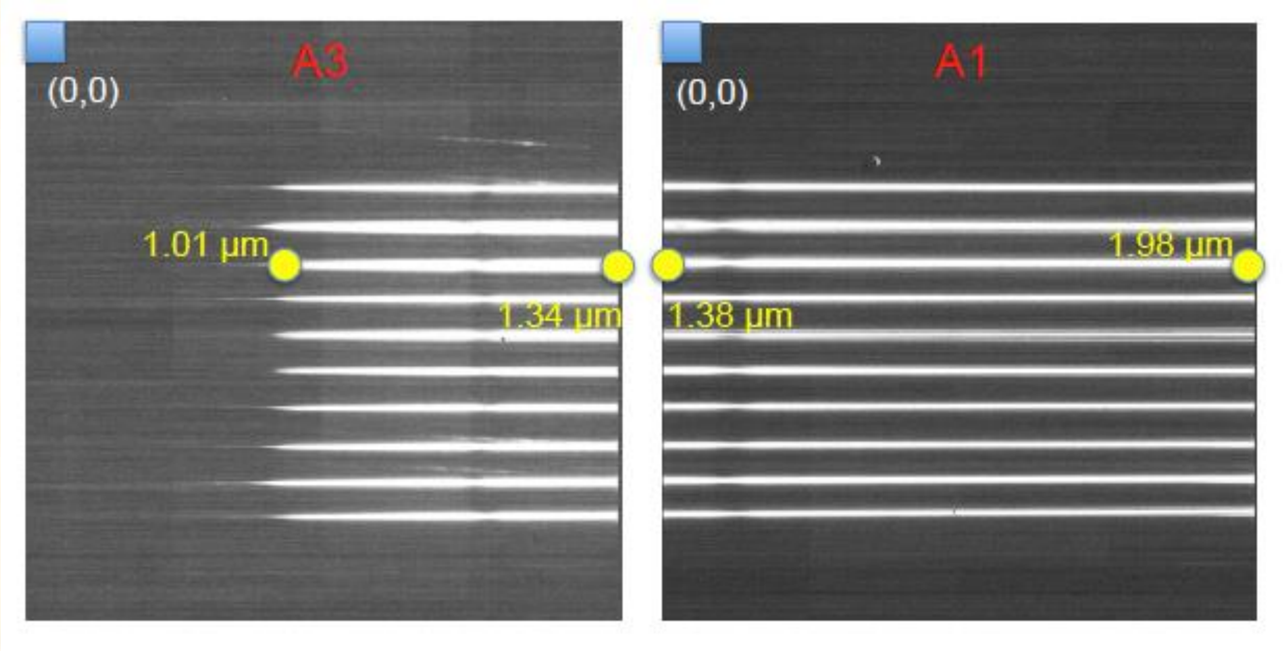
	Readout Pattern	Groups/Int	Integrations/Exp	Total Integrations	Total Exposure Time
⚠ Exposure Time	BRIGHT1	6	1331	1331	21509.173

NIRCam uses the JWST time-series data pipeline



- Users can download & re-run the pipeline with different options, additions, or removals

Future Possible Simultaneous 1 – 2 μm Spectra



- DHS elements disperse ~40% JWST's light onto 2 NIRCam SW detectors with a small gap in-between

- Dispersed Hartmann Sensor (DHS) elements in the SW channel of NIRCam provide 1 – 2 μm spectra using 10 sub-apertures of the JWST pupil, potentially allowing simultaneous spectra of bright stars during LW grism observations
- This is not an approved science mode for Cycle 1; it may be approved for later cycles. There may be limitations on spectra.

See Schlawin+ (2017) PASP

The End